STANDARD METRICS AND METHODS FOR CONDUCTING AVIAN/WIND ENERGY INTERACTION STUDIES

Richard L. Anderson, California Energy Commission, 1516 Ninth Street, Sacramento, CA 95814, USA
Holly Davis, National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden CO 80401-3393, USA
William Kendall, National Biological Service, Patuxent Wildlife Research Center, 11510 American Holly Drive, Laurel, MD 20708-4017, USA
Lawrence S. Mayer, Office of Research, Good Samaritan Regional Medical Center, 1301 N. 12th Street, Suite 509, Phoenix AZ 85018, USA
Michael L. Morrison, Department of Biological Sciences, California State University Sacramento, CA 95819, USA
Karin Sinclair, National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, CO 80401-3393, USA
Dale Strickland, Western Ecosystems Technology, Inc., 2003 Central Avenue, Cheyenne, WY 82001, USA
Steven Ugoretz, Wisconsin Department of Natural Resources, 101 S. Webster Street, Madison, WI 53707-7921, USA

The awareness of the problem of avian fatalities at large scale wind energy developments first emerged in the late 1980's at the Altamont Pass Wind Resource Area (WRA) in Central California, U.S.A. Observations of dead raptors at the Altamont Pass WRA (Anderson and Estep 1988, Estep 1989) triggered concern on the part of regulatory agencies, environmental/conservation groups, resource agencies, and wind and electric utility industries. This led the California Energy Commission (CEC) staff, along with the planning departments of Alameda, Contra Costa, and Solano counties, to commission a study of bird mortality at the Altamont Pass WRA, California (Orloff and Flannery 1992).

In addition to the Altamont Pass WRA, other studies and observations have established that windplants kill birds. Depending upon the specific factors, this may or may not be a serious problem. Although many bird species are affected, raptors have received the most attention (Anderson and Estep 1988, Estep 1989, Howell and Noone 1992, Orloff and Flannery 1992, Hunt 1994, Luke and Watts 1994, Martí 1994, Howell 1995). The emphasis on raptors appears to be for several reasons: 1) eagles are afforded more protection under the federal Bald Eagle Protection Act than other federal and state protected migratory birds, and 2) raptors are symbolic megafauna and have greater emotional value than smaller species to many people. Raptor populations also tend to have smaller numbers of breeding adults and a lower tolerance for additive fatalities.

Other WRA studies have documented deaths of songbirds (Orloff and Flannery 1992, Pearson 1992, Winkelmann 1994, Higgins et al. 1995), water birds (Pearson 1992, Winkelmann 1994), and bats (Higgins et al. 1995). Generally, these have been common species in those areas, not subject to the degree of concern associated with raptor fatalities.

The current level of scrutiny and caution exhibited during the permitting of a new windplant development in the United States results in costly delays and studies. This is occurring during a highly competitive period for electrical production companies in the United States of America. Clarification of the bird fatality issue is needed to bring it into perspective. This means standardizing metrics, defining terms, and recommending methods to be used in addressing or studying wind energy/bird interactions.

COORDINATION

In 1992, CEC staff and the Pacific Gas and Electric Company sponsored a workshop that brought the wind energy and avian stakeholder groups together to discuss the issue and approaches to address it. This was the initial step in the development of a nationwide approach.

Other activities included the initiation of a research program directed by a wind energy company, which focused on the sensory and behavioral aspects of avian interactions with wind energy facilities. At about the same time, the National Wind Coordinating Committee (NWCC) was being formed to address all of the issues affecting the development of wind energy in the United States.

In July 1994, a larger national workshop was held, sponsored by the National Renewable Energy Laboratory (NREL), the U.S. Department of Energy, the American Wind Energy Association, the National Audubon Society, the Electric Power Research Institute, and the Union of Concerned Scientists. That workshop attempted to bring together all of the threads of information and concern about the issue. One major focus was to systematize the search for the factors responsible for avian deaths from wind energy facilities, and to place efforts to reduce fatalities on a firm, scientific basis. A dialogue between the regulators and other interest groups and the ornithological research community was needed to focus research on the questions that had to be answered to site facilities responsibly, and reduce fatalities at existing facilities. Ornithologists, bio-statisticians, and risk scientists were brought into the discussion at the July workshop.

Shortly afterward, the NWCC's Avian Subcommittee was formed to carry on the work begun at the workshop of identifying and setting priorities for wind energy/avian interaction studies and other activities addressing the issue. The Subcommittee has provided advice to funding agencies, facilitated the development of standard protocols for conducting wind energy/avian interaction studies, as reported in this paper, and promoted communications among participants in wind energy developments regarding approaches to resolve the issue.

In September 1995, the Avian Subcommittee and NREL sponsored a second national workshop in Palm Springs, California near a major wind energy development area, to facilitate communications between avian researchers and a diverse stakeholder group. The meeting produced a recommendation that a group of ornithologists, statisticians, and environmental risk specialists develop a set of standard metrics and methods for studying wind energy/avian interactions. This product would describe standard measurements, concepts, and methods and allow studies in different areas to be compared, making it easier to identify causal factors in wind energy/avian interactions.

The momentum for this document was carried on by NREL and the Avian Subcommittee. NREL personnel developed strategy for making this document a reality. They also selected a writing team and a review team composed of members of the main stakeholder groups. The writing team met and drafted an outline, which was subjected to a stakeholder and peer review. This document will be complete in late fall of 1997.

Guidelines Writing Team

Richard Anderson	California Energy Commission
Holly Davis	National Renewable Energy Laboratory
William Kendall	National Biological Service
Michael Morrison	California State University Sacramento

Karin Sinclair	National Renewable Energy Laboratory
Dale Strickland	Western EcoSystems Technology, Inc.

Guidelines Review Team

Donald Bain	Oregon Department of Natural Resources
Keith Bildstein	Hawk Mountain Sanctuary
Sidney Gauthreaux	Clemson University
Walter George	Bureau of Land Management
Thomas Gray	American Wind Energy Association
Lawrence Mayer	Good Samaritan Region Medical Center
Kenneth Pollock	North Carolina State University
Steven Ugoretz	Wisconsin Department of Natural Resources

METRIC AND METHODS

All stakeholders decided it was important to set clear study objectives, use sound scientific sampling protocols, and employ standard and widely accepted field measurement methods. These repeatable methods would require the flexibility to accommodate varying research objectives while resulting in data that can be compared and pooled from multiple research efforts throughout the nation and world. The following describes the framework of metrics, methods, and concepts endorsed by the stakeholders. Over time, the cumulative results will become increasingly beneficial.

Objectives

The objectives of standard metrics and methods are:

1. To promote the use of sound scientific principles in the collection of data necessary for the responsible permitting and development of windplants.

2. To provide a reference for use by all stakeholders in assembling an adequate body of information to:

   a. assess the effects of a windplant project on all bird resources.
   b. aid in assessing the suitability of a proposed windplant.

3. To provide sufficiently detailed and clearly understandable methods, metrics, and definitions for use in the study of wind energy/bird interactions.

4. To promote efficient, consistent, cost effective methods which will produce comparable data and reduce overall need for some future studies.

Research studies can be divided into level 1 (general) and level 2 (focused special studies). This paper will focus on a discussion of level 1 studies. The methods, measurements, and relationships (metrics) considered level 1 studies are a product of review and consensus by scientists representing multiple stakeholders including: university researchers, agency professionals, utility representatives, environmental groups, and the wind industry. Although each component of the Methodology and Measurements seems simple and straight forward, the details and execution of each is complex. All of these methods, measurements and concepts will be addressed in greater detail in the Guidelines document being prepared by the Avian Subcommittee of the National Wind Coordinating Committee.

Methodology and Measurements

Bird Utilization Counts - These are conducted to document bird use at study sites. They are conducted in repeatable ways using standard methods, so that results can be compared with bird utilization counts from other studies. The Bird Utilization Counts are conducted during defined time periods and during appropriate seasons to document behavior and relative abundance of birds using the area. While turbine and wind noise can mask bird calls, there are cases where the use of bird calls may be desirable. In Before-After-Control-Impact (BACI) methodology, the use of bird calls for measuring utilization levels could result in unacceptable bias for the Before and Control locations when compared to the added noise of operating wind turbines in the After and Impact areas. Each situation must be considered specifically with appropriate and supportable decisions made. This will insure that turbine noise will not bias Bird Utilization Counts and subsequent Bird Utilization Rates. We suggest recording all birds detected by sight and sound and documenting the method of detection (e.g., sight, sound, both). The method of detection can be considered during data analysis. Situations with many birds and few birds may require modification to Bird Utilization count methods. Variable and fixed plot surveys may be selected to accommodate the situation. In either case, the distance from the observer to each bird should be estimated and documented. In situations when birds are numerous, instantaneous counts could be made every one minute (or other time interval). The utilization count methodology is flexible and accommodating. Bird activities documented include: flying, perching, soaring, hunting, foraging, duration of time observed, and behavior close ($\leq$50 m) to WRA structures. The height above ground and the horizontal or line of sight distance each bird is from the observer and wind turbine should be documented.

Bird Utilization Rate - Bird Utilization Rate is derived from the Bird Utilization Counts. The Bird Utilization Rate is the number of birds detected utilizing the area (e.g., a defined area such as 50m radius or per square meter) during the Bird Utilization Count time period. Rates can be developed for species, other taxonomic groups, all birds observed, average duration of bird presence in the area or cumulative bird minutes utilizing the area. These and other rates can be developed for specific covariates such as: natural communities, seasons, and distance from nearest turbine.

Example formulas for Bird Utilization Rates are:

$$\frac{\textbf{No. of birds observed}}{\textbf{Time or Time and area}} = \textbf{Bird Utilization Rate}$$

$$\frac{\textbf{Total minutes all birds observed}}{\textbf{No. of birds/time or /time and area}} = \textbf{Average Utilization Minutes}$$

$$\frac{\textbf{No. of birds observed}}{\textbf{Time/meter}^2} = \textbf{Bird Utilization Rate Per Square Meter}$$

Dead Bird Search - Dead Bird Searches are conducted in a defined area, which may include the complete project site or a sample of a larger project site. Complete coverage of the search area is important in detecting dead birds. The number of dead birds or dead bird parts found at each search site is documented. The search area may be circular, rectangular, or square, and be of varying sizes. The methodology allows this flexibility. Search area can be discussed as fatalities per meter square or other size area, as long as the sample methodology has been documented adequately to make inter-study comparisons. Documented information may include: bird species, sex, and age, estimated time since death, cause of death, description of injury, vegetation series, distance to nearest turbine, distance to nearest structure, and distance to important habitat or topographic features. The information collected will allow a variety of analyses. Depending on study objectives, blind necropsies may be performed or required during this study phase.

Bird Mortality - Bird Mortality is the number of dead birds or dead bird parts documented per defined search area. The methodology allows for flexibility in creating bird mortality metrics. Documentation must be clearly set forth in order to allow comparisons to other rates created from the same methodology.

Example formulas for Bird Mortality are:

$$\frac{\textbf{No. of dead birds}}{\textbf{Defined search area}} = \textbf{Bird Mortality}$$

$$\frac{\textbf{No. of dead birds}}{\textbf{Meter}^2} = \textbf{Bird Mortality}$$

Bird Risk - Bird Risk establishes a relationship between bird utilization and bird deaths in an area. Bird Mortality is used as a numerator and the Bird Utilization Rate the denominator to develop a Bird Risk. The numbers of dead birds and bird utilization can increase proportionately without the risk changing. Bird risk can be used to compare risk differences for many variables, such as: near turbine areas and those at varying distances from developed WRA facilities; for species, other taxonomic groups, and all birds observed; for natural communities; seasons; turbine size; structure types; and other variables. Bird Risk can be used to compare risks between WRAs and with other types of facilities such as highways, power-lines, and television and radio transmitter towers. When well documented, many risks can be considered and will be comparable within and between studies. This flexibility allows these methods and metrics to serve the needs of many specific projects and situations.

Example formulas for Bird Risk are:

$$\frac{\textbf{No. of dead birds/ defined area}}{\textbf{No. of birds observed/time or time and area}} = \textbf{Bird Risk}$$

$$\frac{\textbf{No. of dead birds/meter}^2}{\textbf{No. of birds observed/time or time and defined area (m}^2\textbf{)}} = \textbf{Bird Risk}$$

$$\frac{\textbf{Bird Mortality}}{\textbf{Bird Utilization Rate}} = \textbf{Bird Risk}$$

Attributable Risk - The differences in Bird Risk may be used to discuss Attributable Risk. This is the risk that may be attributed to a specific location or situation, such as risk to the birds associated with the developed WRA vs. non-developed, nearby comparison areas or other possible comparisons. As the differences between risks increase, those locations and situations (relevant variables) would be candidates for greater scrutiny and/or more focused studies. The ability to detect differences in risk is an important assumption in these methods and metrics.

Factors Influencing Bird Mortality Estimates

Carcass removal studies and Searcher Detection Efficiency Studies are conducted because Bird Mortality estimates can be affected by carcass removal rate differences and searcher detection differences. These studies and their results are important to conduct and document for each study to facilitate comparison between different studies. In studies with relatively few turbines, where all turbines are monitored, the level (rate) of carcass removal can assist in determining the frequency of dead bird searches needed to provide accurate dead bird number estimates. In studies with large numbers of turbines which can only be sampled, the level of carcass removal can assist in determining the accuracy of relative Bird Mortality numbers.

The Searcher Detection Efficiency Studies and resultant probability of detection (detection rate) are necessary in order to create factors that mathematically describe detection probabilities considering a number of co-variates involved in detection, such as: vegetation structure, vegetation color and density, searcher alertness (1st or 4th area searched in a day) or shadow effects (sunlight levels and angles) and possibly others. Some of these determinations are useful for creating factors for a specific study, and some are important for comparing the results to another study. Therefore, these studies and subsequent rates may provide valuable information for a particular study, for other study comparisons, or both.

Carcass Removal Study - In this study a known number of bird carcasses are placed at randomly chosen locations and monitored for removal by scavengers or by other means. Carcass removal activity can be quantified and calculated as a rate. This allows for comparison of carcass removal within WRAs or between different WRAs. If not detected, significant carcass removal rate differences would result in misleading Bird Mortality and subsequent Bird Risk.

Carcass Removal Rate - This is the rate at which bird carcasses are removed by scavengers or by other means. The results are used to adjust the number of dead birds detected.

A formula for the average time until carcass removal is:

$$\frac{\sum \text{Days for each carcass to be removed}}{\text{Number of carcasses}} = \text{Average time for removal}$$

Searcher Detection Efficiency Study - This is a designed study that includes placing a known number of dead birds or bird parts in a variety of locations with differing vegetative structure and color (green or brown). These searches take place throughout the day with differing sunlight angles (shadows) and differing observer alertness (1st, 2nd, 3rd search). Dead Bird Searches are then conducted and the results for each researcher are compared with the known number of dead birds. The detection success can be quantified and the probability of detection determined.

Searcher Detection Rate - This is a measure of the searchers detection probability in varying vegetative conditions, by time of day, and by 1st, 2nd, 3rd, etc. search of the day.

A formula for searcher detection rate is:

$$\frac{\textbf{No. of carcasses found}}{\textbf{No. of carcasses placed}} = \textbf{Searcher Detection Rate (P)}$$

Rotor Swept Area Metrics

Rotor Swept Hour and Rotor Swept Hour Risk - These measurements will look at bird use, mortality, and risk associated with different sized turbines. The rotor swept area has been treated in past instances as having a direct relationship with Bird Mortality. There is no data to support the notion that larger rotor swept areas along with other turbine characteristics may cause more or less fatalities with constant Bird Utilization Rates. Addressing this issue requires standardizing the measurements and relationship created so that the size differences can be isolated for the comparison. Rotor Swept Hour combines the size of the area swept by the rotor (rotor swept area) with the time it operates. Rotor swept hour risk will allow for comparison of risk associated with different rotor swept areas or turbine sizes in relation to the time they operate.

The formula for Rotor Swept Hour is:

$$\textbf{Rotor swept area (m}^2\textbf{) x hours of operation = Rotor Swept Hour}$$

This formula implies that a large turbine operating a low percentage of the time is comparable to a smaller turbine which operates a high percentage of the time. This may or may not be true. Whatever the case, differences in mortality, utilization and risk can be determined and normalized to compare the risk of each turbine.

Rotor Swept Hour Risk combines the rotor swept area, and time of operation (RSH), with risk to create Rotor Swept Hour Risk. The inverse of the dividend is used in order to more easily comprehend the comparisons between RSHR.

The formula for Rotor Swept Hour Risk is:

$$\textbf{Rotor Swept Hour Risk (RSHR)} = \frac{\textbf{1}}{\textbf{Rotor swept hour}} \textbf{ x Bird Risk}$$

In some instances, operation time may be considered as proprietary information and not available to researchers. In these cases, rotor swept area and rotor swept area risk may have to be substituted for RSHR. In other projects, an estimate of operation time may be developed from wind speed information and cut-in and cut-out specifications for the turbines in the study areas.

Other Studies

All Day Bird Activity Monitoring - This study documents day long bird activity during the various seasons. This information can be used to normalize Bird Utilization Rates for different time periods of the day or between different WRAs.

Specialty Studies - These are modeling or manipulative studies used to investigate specific questions. These are focused (level two) studies, usually conducted in response to findings of a more general (level 1) study. Examples of these types of studies are:

- Population Studies
- Risk Reduction Studies (reduce effects)

These studies are beyond the scope of the paper, and require additional metrics and methods.

CONCLUSIONS

The task of understanding and reducing avian fatalities due to interactions with wind turbines provides a good example of how science and policy can interact. The stakeholder groups that make up the National Wind Coordinating Committee, and its Avian Subcommittee, recognized that it was important to use credible science to produce good policy. They also recognized that all of the stakeholder groups have to be involved to establish scientific credibility. The Avian Subcommittee's work has helped to focus and standardize studies in a productive and cooperative manner.

The Subcommittee hopes that the methods and metrics developed and discussed in this paper will be reviewed and adapted for use by the ornithological community in all applied studies of bird interactions with wind turbines, and potentially other technologies. This should allow information to be pooled and compared between regions of the United States, and other countries around the world where wind energy development may occur. By doing this we can reduce the impacts on birds from existing facilities, and minimize impacts at new locations.

GUIDELINES DOCUMENT

The avian subcommittee of the National Wind Coordinating Committee has established a Guidelines Subcommittee to produce the guidelines document:

"Guidelines and Suggested Methods for Studying Wind Energy/Avian Interactions"

This document has been drafted and will be available in late fall of 1997. For information on availability please contact:

Karin Sinclair, Avian Projects Manager
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, CO 80401-3393, USA
Phone: (303) 384-6946
FAX: (303) 384-6901
E-mail: Karin_sinclair@nrel.gov